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Distribution and seasonal occurrence of the lycaenid, *Zizina emelina* (de l'Orza) (Lepidoptera, Lycaenidae), around the Osaka International Airport, central Japan

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Abstract The distribution and seasonal occurrence of the lycaenid butterfly, *Zizina emelina* (previously *Zizina otis emelina*), were investigated at 99 sites of grassy sites, including known previous locations around the Osaka International Airport (OIA) on the boundary between Osaka and Hyogo Prefectures, central in Japan between 2000 and 2007. In addition, eggs obtained from 31 field-collected females were reared into adults under quasi-natural conditions in different seasons to infer the developmental period in the field. *Zizina emelina* were seen at 43 of the 99 survey sites. Of the 43 sites, 15 and 21 were on or near embankments of the Inagawa River and in the grass of the urbanized region around the OIA, respectively. In contrast, this species was recorded from only seven survey sites in the Senri Hills, located to the northeast of the OIA. The density of adults was especially high at 12 sites in the vicinity of the OIA and at one in the Senri Hills. The population living around the OIA depends on white clover, *Trifolium repens* (Fabaceae), and/or Japanese clover, *Kummerovia striata* (Fabaceae), as larval food plants rather than the bird's-foot trefoil, *Lotus corniculatus* (Fabaceae), the major food plant of *Z. emelina* in Japan, which was not found in the area around the OIA. In contrast, in the Senri Hills, *Z. emelina* and *L. corniculatus* were observed to co-occur at two sites, where the eggs of the butterfly were found on the plant. From the results of field observations and rearing experiments, we inferred *Z. emelina* has 6–7 generations in the field around the OIA, with the adult flight season being between April and November. Intriguingly, some field-collected females produced no male offspring (*i. e.* all F_1 adults were female).

Key words *Zizina emelina*, distribution, food plant, seasonal occurrence, Osaka, Hyogo, Japan.

Introduction

In mainland Japan, the lycaenid butterly, *Zizina emelina* (de l'Orza) (previously *Zizina otis emelina*) (Lepidoptera, Lycaenidae), has previously been recorded from 36 prefectures in Honshu, Shikoku and Kyushu, but colonies are now limited to 17 prefectures owing to destruction of the butterfly's habitat and loss of early successional grasslands due to changes in traditional land use practices (Ministry of Environment Japan, 2006). This species was widely distributed in Osaka Prefecture until the 1950s (Hiura, 1970; Ichii, 1972; anonym, 1948; Sugishita, 1949; Yasuda & Miyamoto, 1949; Tanaka, 1949; Yoshizaka, 1950, 1954, 1953; Hatanaka, 1951; Kishi, 1962; Tada & Nakajima, 1981), but there has been no record from southern Osaka Prefecture for nearly half a century. In northern Osaka Prefecture, this species has recently been reported from a few limited sites on the embankment of the Inagawa River (Watanabe, 2005; Tsunefuji, 2005; Morichi & Minohara, 2005), although records from the Senri Hills extend only until the 1980s (Sugitani, 1960; Yamamoto, 1967; Imai, 1972; Arita, 1983; Uyama, 2003; Hase, 2003; Natsuaki, 2007) and those from the Yodogawa River basin extend only until the 1960s (Kurihara, 1943; Hiura, 1970; Imai, 1972). In these locations most habitat areas have been destroyed or altered markedly by recent urban expansion.

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The Osaka International Airport (OIA) is located on the boundary between Osaka and Hyogo Prefectures, with the north western end of the runway facing the Inagawa River (see Fig. 1). Interestingly, recent records of *Z. emelina* from the Inagawa River have been limited to the east bank of the river near the OIA (Watanabe 2005; Tsunefuji 2005; Morichi & Minohara, 2005). The bird's-food trefoil, *Lotus corniculatus* (Fabaceae), the major food plant of *Z. emelina* in Japan, has become extinct or extremely rare on the embankment of the Inagawa River, although it is thought that *Z. emelina* used to utilize *L. corniculatus* in this area (Tsugata & Sakuratani, 1992; Morichi & Minohara, 2005). Nakamura and Tanishi (1988) observed a female *Z. emelina* lay eggs on white clover, *Trifolium repens*, (Fabaceae) on the embankment of the Inagawa River in 1987.

Accordingly, we conducted investigations for habitats of *Z. emelina* and its food plant around the OIA including on the Senri Hills from 2000 to 2007. In addition, we reared larvae of *Z. emelina* using leaves of *T. repens* under quasi-natural conditions to elucidate whether this species utilizes the plant as a food plant in the field.

Study sites and methods

We investigated the distribution of *Z. emelina* and its food plants at a total of 99 survey sites around the OIA via more than 100 surveys between October, 2000 and February, 2007. Of the 99 sites, 7 (Sites I1–7), 59 (T1–59), 7 (S1–7) and 11 (M1–11) were located in Ikeda, Toyonaka, Suita and Minoo Cities, respectively, in northern Osaka Prefecture, and 9 (B1–9) and 6 (A1–6) sites were located in Itami and Amagasaki Cities, respectively, in eastern Hyogo Prefecture (see Table 1 and Fig. 1). The 99 sites comprised grassy areas of various sizes on or near embankments of the Inagawa, Mogawa and the Kanzakigawa Rivers (25 sites), and others in parks, playgrounds, vacant land, cemeteries, and a university campus etc. in the urbanized area around the OIA (30 sites) and on the Senri Hills to the east of the OIA (44 sites).

The numbers of male and female *Z. emelina* adults, and the numbers of candidate food plants were recorded at each site around the OIA between 2002 and 2004, between April 27 and November 9 in 2002, between April 6 and November 8 in 2003, and between April 17 and December 14 in 2004. We estimated the number of generations per year in the area around the OIA using changes in the number of adults, the sex ratio, and the freshness of individuals' wings in sites with a stable population.

Eggs were obtained from field-collected females of *Z. emelina* that had been captured around the OIA in different seasons between 2002 and 2005, and hatching larvae were reared to adults under quasi-natural conditions to determine whether this species utilizes *T. repens* as a food plant in the field and also to determine when the developmental period is in each season. Fresh leaves of *T. repens* were provided as the diet for larvae.

Results and discussion

Distribution of *Z. emelina* and food plants

Adult *Z. emelina* were found at 43 of the 99 survey sites investigated in this study (Table 1 and Fig. 1). Most of the sites where *Z. emelina* was seen were located along the Inagawa River and/or around the OIA: of the 43 sites, 15 were on or near embankments of the Inagawa River, and 21 were in grassy areas in the urban region around the OIA, respectively. In contrast, this species was recorded from only seven sites in the Senri Hills (-to the northeast of the OIA): four sites in the Osaka University campus, two sites in residential areas,

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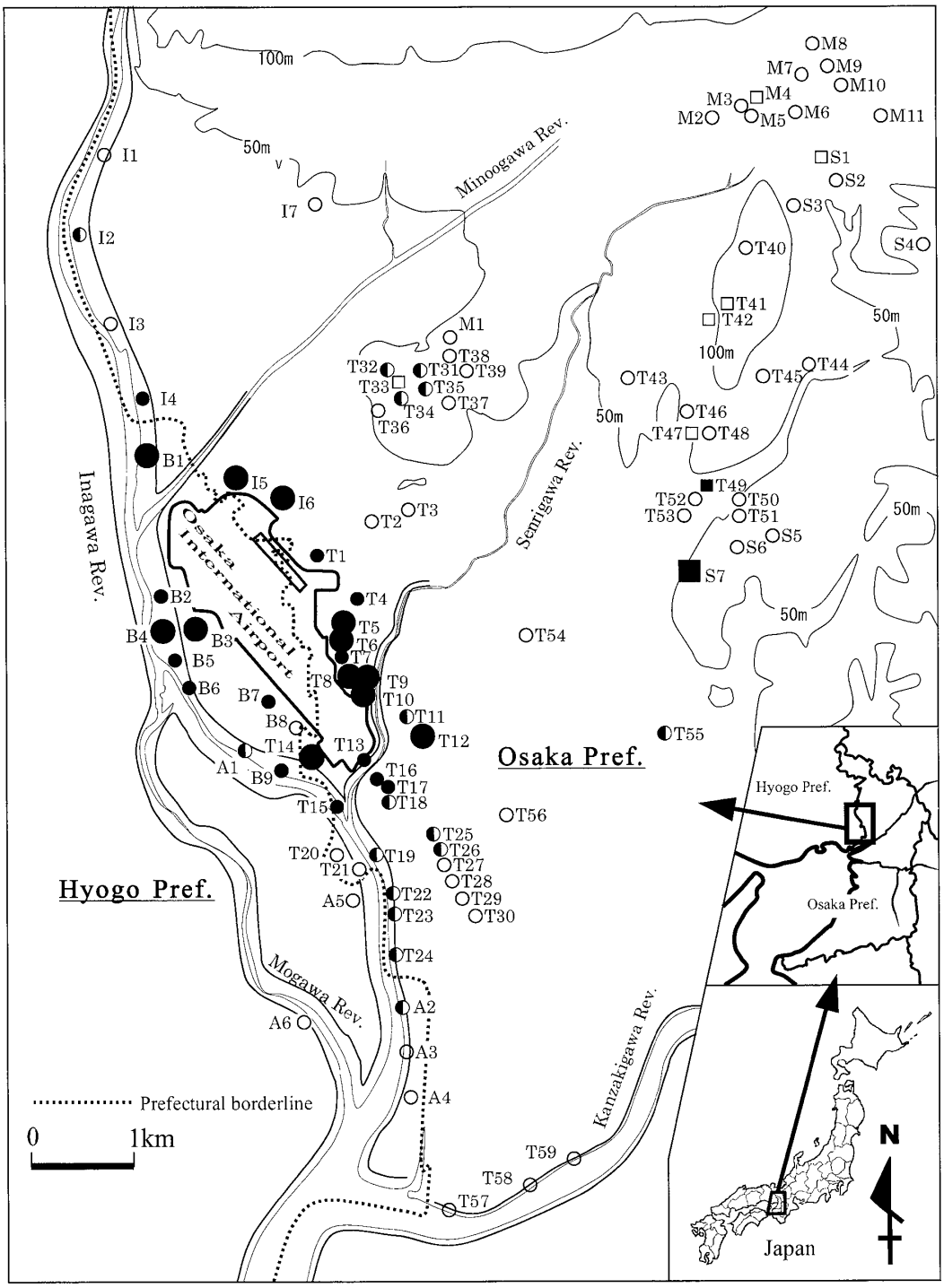

Fig. 1. Distribution and adult density of the lycaenid butterfly, *Zizina emelina*, at 99 sites around the Osaka International Airport where investigations were conducted from 2000 to 2007. Each plot indicates each of the 99 study sites, where adults were seen (closed plot) or not seen (open plot), with the size and shape of plot showing the approximate abundance of adult (large; abundant or common, small; rare or occasional (half closed)) and the existence (square) or absence (circle) of the bird's-food trefoil, *Lotus corniculatus* (Fabaceae), a major food plant of *Z. emelina* in Japan, respectively.

●○ ; sites without *L. corniculatus*, ■□ ; sites with *L. corniculatus*.

●■; *Z. emelina* adults abundant/common, ●■; few, ◐; occasional, ○□; none.

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Table 1. Investigation period, date of the first record of the adults, adult density, candidate for foodplant, sunniness, height of grass, topography and location of the 99 study sites around the Osaka International Airport (OIA) where the investigation for *Zizina emelina* was done from 2000 to 2007.

Sites	Investigation period	The first record of adults	Adult density[1]	Candidate for food-plant[2]			Sunniness[3]	Height of grass[4]	Topography[5]	Location[6]
				T. repens	*L. corniculatus*	*K. striata*				
Osaka Prefecture										
Ikeda City										
I1 Muromachi	12. v. 2001–30. x. 2005	–	–	Yes	No	Yes	sunny	short	riverbank	W of Ikeda Station.
I2 Momozono	12. v. 2001–30. x. 2005	30. x. 2005	±	Yes	No	Yes	sunny	short	riverbank	Northern Inagawa Athletic Park
I3 Koda	7. x. 2000–30. x. 2005	–	–	Yes	No	Yes	sunny	short	riverbank	Southern Inagawa Athletic Park
I4 Daihatsucho	7. x. 2000–30. x. 2005	7. x. 2000	+	Yes*	No	Yes	sunny	short	riverbank	N of Gunkobashi Br.
I5 Toyoshima-minami	5. x. 2002–15. x. 2006	5. x. 2002	+++	Yes*	No	No	sunny	short	flat	1-, 2-chome of Toyoshima-minami
I6 Kuko	5. x. 2002–15. x. 2006	5. x. 2002	+++	Yes*	No	Yes*	sunny	short	flat	NE of Terminal building of OIA
17 Midorigaoka	29. x 2006	–	–	No	No	No	–	–	hill	Residential area at E of Ikeda Station (see Text)
Toyonaka City										
T1 Hotarugaike-nishimachi	17. v. 2003–5. xi. 2005	18. viii. 2003	+	Yes*	No	No	sunny	short	flat	SE of the Terminal building of OIA
T2 Hotarugaike-nakamachi	11. x. 2004–5. xi. 2005	–	–	Yes	No	No	sunny	short	flat	Hotarugaike Park
T3 Toneyama	19. viii. 2003–28. ix. 2003	–	–	Yes	No	No	sunny	short	hill	N of Toneyama Hospital
T4 Minowa	17. v. 2003–8. vii. 2006	7. ix. 2003	+	Yes	No	No	sunny	short	flat	In and around Minowa 3 chome Park
T5 Hashirii 1	20. vii. 2002–3. ix. 2005	20. vii. 2002	+++	Yes*	No	Yes*	sunny	short	flat	NNE of the mouth of Airport Subterranean Tunnel
T6 Hashirii 2	16. vi. 2002–15. x. 2006	16. vi. 2002	+++	Yes*	No	Yes	sunny	short	flat	S of Site T5
T7 Hashirii 3	20. vii. 2002–15. x. 2006	20. vii. 2002	+	Yes	No	No	sunny	short	flat	S of Site T6
T8 Hashirii 4	1. x. 2002–5. xi. 2005	1. x. 2002	++	Yes*	No	Yes	sunny	short	flat	W of Shimmeibashi Br.
T9 Hashirii 5	20. vii. 2002–15. x. 2006	20. vii. 2002	+++	Yes*	No	Yes*	sunny	short	flat	W of Shin-Katsubebashi Br.
T10 Hashirii 6	5. v. 2003–15. x. 2006	29. vi. 2003	++	Yes	No	No	sunny	short	flat	50m W of Shin-Katsubebashi Br.
T11 Katsube 1	23. xi. 2004–5. xi. 2005	23. xi. 2004	±	Yes	No	No	sunny	short	flat	S of Sinmeibashi Br.

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T12 Katsube 2	15. ix. 2002–15. x. 2006	15. ix. 2002	++	Yes*	No	No	sunny	short flat	NNE of Nashitakabashi Br.
T13 Minamikukocho	12. v. 2002–11. x. 2004	12. v. 2002	+	Yes	No	No	sunny	short flat	NNE of Harada-o-hashi Br.
T14 Harada-nishimachi 1	14. vii. 2002–11. x. 2004	3. v. 2003	++	Yes*	No	Yes	sunny	short flat	Circumference of Clean Sports Land
T15 Harada-nishimachi 2	21. ix. 2002–30. x. 2005	21. ix. 2002	+	Yes	No	Yes	sunny	short riverbank	S of Harada-o-hashi Br.
T16 Haradanaka 1	10. iii. 2002–23. xi. 2004	14. ix. 2003	+	Yes	No	No	sunny	short flat	E of Harada-o-hashi Br.
T17 Haradanaka 2	10. iii. 2002–10. x. 2005	3. xi. 2004	+	Yes*	No	No	sunny	short flat	E of Harada-o-hashi Br.
T18 Haradaminami	14. ix. 2003–3. xi. 2004	3. xi. 2004	±	Yes	No	No	shady	short flat	S of Site 17
T19 Tokuranishi 1	10. iii. 2002–30. x. 2005	19. x. 2003	±	Yes*	No	No	sunny	short riverbank	NW of Tokurabashi Br.
T20 Tokuranishi 2	19. x. 2003–8. xi. 2003	–	–	Yes	No	Yes	shady	short flat	ENE of Tokurabashi Br.
T21 Tokuranishi 3	3. xi. 2002–8. xi. 2003	–	–	Yes	No	No	sunny	short riverbank	NW-SE of Tokurabashi Br.
T22 Tokura	1. x. 2003–30. x. 2005	24. x. 2004	±	Yes	No	Yes	sunny	short riverbank	N of Shin-nan-en-bashi Br.
T23 Kozushima	1. x. 2003–22. x. 2006	24. x. 2004	±	Yes	No	No	sunny	short riverbank	N of Shin-nan-en-bashi Br.
T24 Imazaikecho	24. x. 2004–22. x. 2006	24. x. 2004	±	Yes	No	No	sunny	short riverbank	N of Meishin Expressway
T25 Tokura-higashi	23. x. 2004–9. x. 2005	23. x. 2004	±	Yes	No	No	sunny	short flat	W of Teshima Gymnasium
T26 Hattori-nishimachi	16. x. 2004–8. vii. 2006	16. x. 2004	±	Yes	No	No	sunny	short flat	S of Teshima Heated Swimming Pool
T27 Hattori-kotobukicho 1	23. x. 2004–9. x. 2005	–	–	Yes	No	No	sunny	short flat	SE of Site T26
T28 Hattori-kotobukicho 2	23. x. 2004–9. x. 2005	–	–	Yes	No	No	sunny	short flat	SE of Site T27
T29 Hozumi	21. xi. 2004–30. x. 2005	–	–	Yes	No	No	sunny	short flat	Hozumi-minami Park
T30 Nodacho	21. xi. 2004	–	–	Yes	No	No	sunny	short flat	N of Noda Municipal Elementary School
T31 Machikaneyamacho 1	28. ix. 2003–15. x. 2006	28. ix. 2003	±	Yes	No	No	shady	short hill	NE of Nakayamaike Pond
T32 Machikaneyamacho 2	28. ix. 2003–15. x. 2006	30. vii. 2005	±	Yes	No	No	sunny	short hill	N of Nakayamaike Pond
T33 Machikaneyamacho 3	28. ix. 2003–15. x. 2006	–	–	Yes	Yes	No	sunny	short hill	NE of Nakayamaike Pond
T34 Machikaneyamacho 4	28. ix. 2003–15. x. 2006	28. ix. 2003	±	Yes	No	No	sunny	high hill	E of Nakayamaike Pond
T35 Machikaneyamacho 5	28. ix. 2003–15. x. 2006	28. ix. 2003	±	Yes	No	No	shady	short hill	E of Nakayamaike Pond
T36 Machikaneyamacho 6	28. ix. 2003–3. ix. 2005	–	–	Yes	No	No	sunny	short hill	S of Osaka University Toneyama Dormitory
T37 Machikaneyamacho 7	28. ix. 2003–3. ix. 2005	–	–	Yes	No	No	sunny	short hill	S of Ubayaike Pond
T38 Miyayamacho 1	8. xi. 2003–30. vii. 2005	–	–	Yes	No	No	sunny	high hill	S of Shibahara Waterworks
T39 Miyayamacho 2	8. xi. 2003	–	–	Yes	No	No	shady	short hill	Akasakakamiike Park
T40 Shinsenri-kitamachi	9. x. 2005	–	–	–	–	–	–	hill	Unspecified. N of Senri-chuo Station (see Text)
T41 Shinsenri-nishimachi	5. x. 2003–15. x. 2006	–	–	No	Yes	No	sunny	short hill	Senri Green Zone in 3 chome, Shinsenri-Nishimach
T42 Midorigaoka	8. vii. 2006–15. x. 2006	–	–	Yes	Yes	Yes	sunny	short hill	SE of Toyonaka Prefectural High School
T43 Shoji	5. x. 2003–30. vii. 2005	–	–	Yes	No	No	sunny	short hill	NW of Shoji Station of Osaka Monorail
T44 Shinsenri-higashimachi 1	5. x. 2003	–	–	Yes	No	No	sunny	short hill	Senrichuo Park

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T45 Shinsenri-higashimachi 2	11. vii. 2003–3. xi. 2004	–	–	Yes	No	No	sunny	short hill	Higashimachi Park
T46 Shinsenri-minamimachi 1	20. xi. 2004–9. ix. 2006	–	–	Yes	No	No	shady	high hill	W of Toyonaka Prefectural High School
T47 Shinsenri-minamimachi 2	13. viii. 2006–9. ix. 2006	–	–	Yes	Yes	No	sunny	short hill	N of Toyonaka Prefectural High School
T48 Shinsenri-minamimachi 3	13. viii. 2006–9. ix. 2006	–	–	Yes	No	No	sunny	short hill	E of Toyonaka Prefectural High School
T49 Shinsenri-minamimachi 4	20. xi. 2004–28. x. 2006	1. vii. 2006	+	Yes	Yes*		No	sunny	short hill NW of Momoyamadai Station
T50 Shinsenri-minamimachi 5	1. vii. 2006–28. x. 2006	–	–	Yes	No	No	sunny	short hill	N of Momoyamadai Station
T51 Shinsenri-minamimachi 6	1. vii. 2006–28. x. 2006	–	–	Yes	No	No	sunny	short hill	NW of Monoyamadai Station
T52 Higashi-toyonakacho	1. vii. 2006–28. x. 2006	–	–	Yes	No	No	sunny	short hill	Ninokiri-ike Park
T53 Higashi-izumigaoka	1. vii. 2006–30. ix. 2006	–	–	Yes	No	No	sunny	short hill	S of Ninokiri-ike Pond
T54 Kitasakurazuka	16. vi. 2002–28. x. 2006	–	–	Yes	No	No	shady	short flat	Daimon Park
T55 Hattoriryokuchi	x. 1999–28. x. 2006	2. ix. 2006	±	Yes	No	Yes	sunny	short hill	Hattori-ryokuchi Park
T56 Sone-minamimachi	21. xi. 2004	–	–	Yes	No	No	sunny	short flat	Teshima Park
T57 Futabacho	24. x. 2004–22. x. 2006	–	–	Yes	No	No	sunny	short riverbank	Riverbank of Kanzakigawa Rev.
T58 Oshimacho	24. x. 2004–22. x. 2006	–	–	Yes	No	No	sunny	short riverbank	Riverbank of Kanzakigawa Rev.
T59 Kamisucho	24. x. 2004–22. x. 2006	–	–	Yes	No	No	sunny	short riverbank	Riverbank of Kanzakigawa Rev.
Suita City									
S1 Fujishirodai 1	28. vi. 2006–6. ix. 2006	–	–	No	Yes	No	sunny	short hill	National Cardiovascular Center
S2 Fujishirodai 2	9. x. 2005	–	–	Yes	No	No	sunny	short hill	NE from Senri-chuo Station
S3 Aoyamadai	9. x. 2005	–	–	–	–	–	–	– hill	NE from Senri-chuo Station (see Text)
S4 Kamiyamada	29. x. 2003	–	–	Yes	No	No	sunny	short hill	Around Osaka University Hospital
S5 Momoyamadai 1	8. vii. 2006	–	–	Yes	No	No	sunny	short hill	E of Momoyamadai Station
S6 Momoyamadai 2	31. v. 2006–9. ix. 2006	–	–	Yes	No	No	sunny	short hill	SW of Momoyamadai Station
S7 Momoyamadai 3	1. vii. 2006–15. x. 2006	1. vii. 2006	+++	Yes*	Yes*	Yes	sunny	short hill	N of Hattori-ryokuchi Park
Minoo City									
M1 Hanjo	8. xi. 2003–12. ix. 2004	–	–	No	No	Yes	sunny	short hill	Minoo City Burial Ground
M2 Hakunoshima 1	21. x. 2006	–	–	Yes	No	Yes	sunny	short hill	Daigujiike Pond and Toriike Pond
M3 Hakunoshima 2	21. x. 2006	–	–	Yes	No	Yes	sunny	short hill	Shinsatsumaike Pond
M4 Hakunoshima 3	21. x. 2006	–	–	Yes	Yes	Yes	sunny	short hill	Gotoike Pond
M5 Hakunoshima 4	21. x. 2006	–	–	Yes	No	Yes	sunny	short hill	Satsumaike Pond
M6 Ishimaru	21. x. 2006	–	–	Yes	No	No	sunny	short hill	Uchikoshiike Pond
M7 Gein	21. x. 2006	–	–	Yes	No	No	sunny	short hill	Gein 3 chome
M8 Gein ~ Aogein	21. x. 2006	–	–	–	–	–	–	– hill	Unspecified (see Text)

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M9 Aogein	21. x. 2006	–	–	No	No	Yes	sunny	short hill	Terraced paddy fields in Aogein 6 chome
M10 Aomadani 1	21. x. 2006	–	–	No	No	Yes	sunny	short hill	Aominami Park
M11 Aomadani 2	21. x. 2006	–	–	Yes	No	No	sunny	short hill	Near Toyokawa Branch Office of Minoo City Hall
Hyogo Prefecture									
Itami City									
B1 Shimogawara	7. x. 2000–30. x. 2005	7. xii. 2000	++	Yes*	No	Yes	sunny	short riverbank	N-S of Gunkobashi Br.
B2 Nakamura	14. x. 2000–30. x. 2005	14. x. 2000	+	Yes	No	Yes	sunny	short riverbank	S of Gunkobashi Br.
B3 Kuwazu	26. ix. 2004–30. x. 2005	26. ix. 2004	++	Yes	No	No	sunny	short flat	ENE of Kuwazubashi Br.
B4 Higashikuwazu	14. x. 2000–30. x. 2005	14. x. 2000	++	Yes*	No	Yes*	sunny	short riverbank	N of Kuwazubashi Br.
B5 Morimoto	5. x. 2002–30. x. 2005	30. x. 2005	+	Yes	No	Yes	sunny	short riverbank	S of Kuwazubashi Br.
B6 Kuchisakai	5. x. 2002–30. x. 2005	30. x. 2005	+	Yes	No	No	sunny	short riverbank	SE of Kozu-o-hashi Br.
B7 Iwaya 1	3. viii. 2003–11. x. 2005	3. viii. 2003	+	Yes	No	No	sunny	short flat	NE of Ebisubashi Br.
B8 Iwaya 2	14. vii. 2002–3. v. 2003	–	–	Yes	No	Yes	sunny	short flat	Kozu Burial Ground
B9 Iwaya 3	5. x. 2002–30. x. 2005	30. x. 2005	+	Yes*	No	No	sunny	short riverbank	ESE of Inagawabashi Br.
Amagasaki City									
A1 Tano	5. x. 2002–30. x. 2005	24. x. 2004	±	Yes	No	No	sunny	short riverbank	W of Inagawabashi Br.
A2 Higasisonoda	24. x. 2004–22. x. 2006	24. x. 2004	±	Yes	No	No	sunny	short riverbank	N of Meishin Express Way
A3 Tonouchi	24. x. 2004–22. x. 2006	–	–	Yes	No	No	sunny	short riverbank	S of Hankyu Railway Kobe Line
A4 Tonouchicho	24. x. 2004–22. x. 2006	–	–	Yes	No	No	sunny	high riverbank	S of Tonouchibashi Br.
A5 Higashisonodacho	3. xi. 2002–8. xi. 2003	–	–	Yes	No	No	sunny	short riverbank	N of Tokurabashi Br.
A6 Zempojicho	27. i. 2007	–	–	Yes	No	No	sunny	short riverbank	S of Sonodabashi Br. (see Text)

[1] +++ abundant, ++ common, +few, ±occasional, -none.
[2] *: eggs and/or larvae were found on the foodplant.
[3] shady: partially shaded with trees.
[4] short; <30 cm, High; >30cm.
[5] riverbank; on/near the embankment of the Inagawa River, hill; on the Senri Hills, flat; grass on the flat land around OIA.
[6] N: north, E: east, S: south, W: west.

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and one site in Hattori-ryokuchi Park.

In the Senri Hills, habitat at three sites, where *Z. emelina* was recorded in the 1970s and 1980s (I7, T40 and S3; Arita, 1983; Uyama, 2003; Hase, 2003; Natsuaki, 2007) no longer existed because residential buildings had been contructed at these locations. Arita (1983) reported this species from a school in Midorigaoka, Ikeda City (I7) in 1983, but no favorite environment for this species was found in the present study. This species was also previously reported from Shinsenri-kitamachi in northern Toyonaka City (T40) in 1971 (Uyama, 2003; Natsuaki, 2007) and Aoyamadai in northern Suita City (S3) in 1975 (Hase, 2003). However, these sites are now occupied by housing complexes, and *Z. emelina* was not found at these sites in our investigation. Although there is a 1941 record of this species around Gein and Aogein (M8) (Sugitani, 1960), no adult was seen at any of the 11 sites in Minoo City investigated in this study. The habitat of *Z. emelina* at site M8 has also disappeared because of housing development.

All 13 sites where adults were commonly or abundantly observed in this study (I5, I6, T5, T6, T8, T9, T10, T12, T14, S7, B1, B3 and B4) were concentrated around the OIA, except for S7, which was in a residential area at Momoyamadai on the Senri Hills (Table 1 and Fig. 1). Five of the sites where adults were most abundantly seen in this study comprised short grass in large vacant blocks of over 2,000 m^2 a each (I6, T5–6 and T9) or short grass along a sidewalk (I5) to the east of the OIA. Two of the sites where adults were commonly seen in this study comprised short grass on the embankment of the Inagawa River, close to the northern (B1) or the western (B4) extent of the OIA. The other four sites where adults were commonly observed in this study comprised short grass in small vacant blocks close to the western (B3), the southern (T14) and the southeastern (T10 and 12) extent of the OIA.

In contrast, most of the 16 sites where a small number of adults were observed (I2, T11, T18–19, T22–26, T31–32, T34–35, T55, A1 and A2) were distributed outside the zone around the OIA that contained the sites densely inhabited by *Z. emelina* (Table 1 and Fig. 1). These sites in which adults were sporadic observed were not considered to contain stable populations, but rather habitats where this species occasionally immigrates to and/or occurs temporarily. Fourteen sites where adults were rarely observed (I4, T1, T4, T7, T13, T15–17, T49, B2, B5–7 and B9) were considered to represent small habitat patches and/or unstable populations. There is an old record of this species from the west bank of the Mogawa River (A6). However, *Z. emelina* was not found at A6 in our investigation, even though the favoured environment remains.

Our results reveal that *Z. emelina* is widely distributed around the OIA in many habitat patces of various sizes, although this species is considered critically endangered in Japan. Adult *Z. emelina* were found not only on the embankment of the Inagawa River, where this species has been known to occur since 1977 (Tohyama, 1989), but also in grassy patches around the OIA and in the Senri Hills.

Our analysis of the distribution of *Z. emelina* suggests that there exist two major populations of this species around the OIA: the close to the OIA and on the embankment of the Inagawa River ("the OIA population"), and one in the Senri Hills ("the Senri population"). Since the density of adults was highest in the vicinity of the OIA, it is quite possible that the OIA population is mainly distributed in the grassy areas running along the runways of the OIA itself. In fact, an adult was seen flying into the airport through the fence near site T8 on October 31, 2004. Field surveys will be needed to determine the distribution of *Z. emelina* in the OIA.

This species was not recorded from Hattori-ryokuchi Park (T55) in previous investigations

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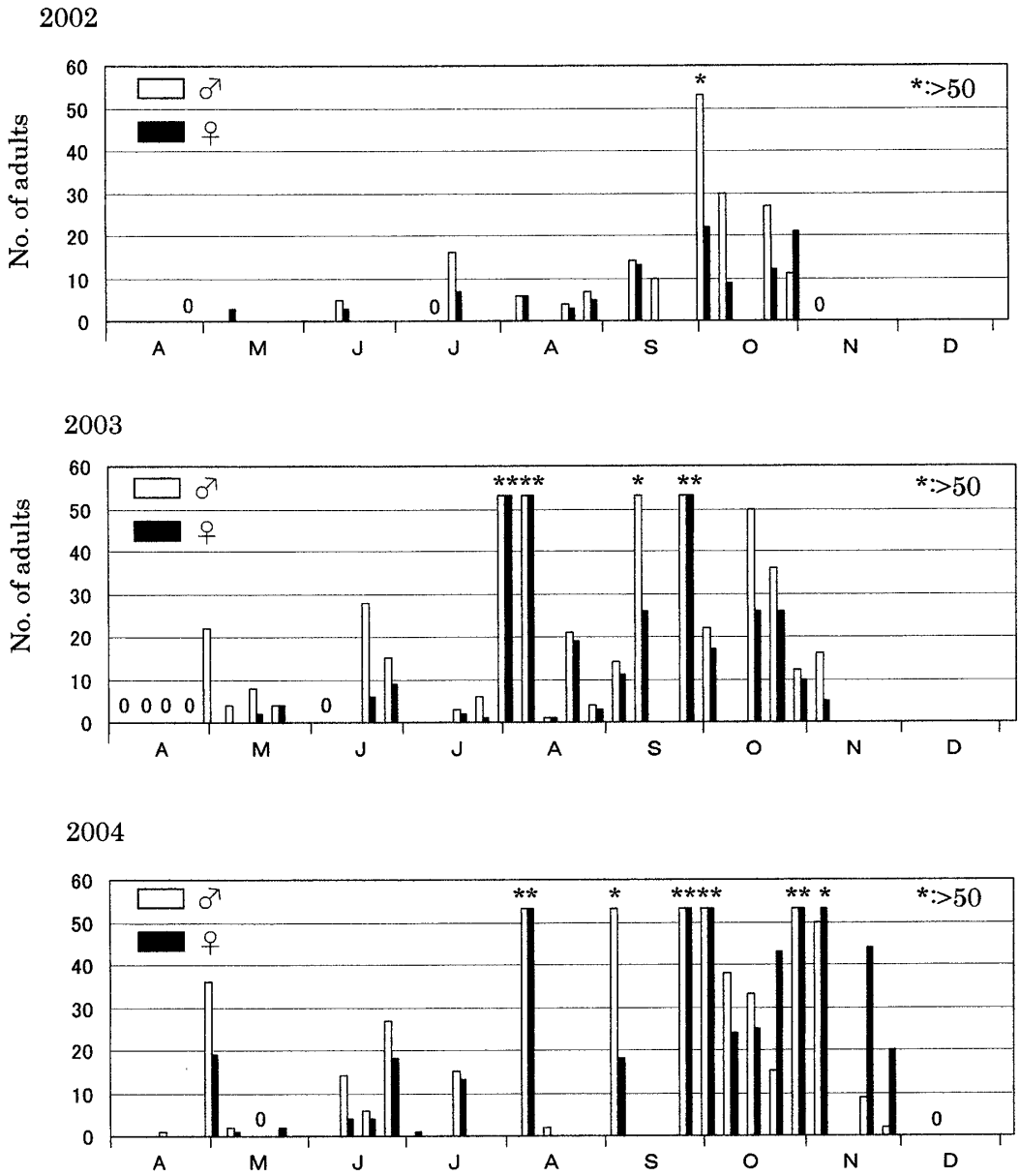

Fig. 2. Seasonal change in numbers of adult males (□) and females (■) of *Zizina emelina* in the field around the Osaka International Airport in 2002, 2003 and 2004. "0" in the figure indicates that no adult was found on the day. *: more than 50 individuals

carried out between 1973 and 2000 (Takahashi, 2001), in 1988 (Ishii *et al.*, 1991), between 1998 and 1999 (Aoyagi and Yoshio, 2002) and between 1999 and 2005 (Minohara, 2001–2006). The first record of *Z. emelina* in this park was in mid-November 2005, when a male adult was seen nectaring from a flower of *Argyranthemum frutescens* (Ueyama, 2006). Thereafter, Minohara (2007), one of the present authors, recorded a female from the park in early September 2006. The adult found in the park could have originated from the OIA or the Senri population.

Foodplants

Interestingly, *L. corniculatus*, the major food plant of *Z. emelina*, was not found at 41 of the 43 sites where *Z. emelina* adults were seen in this study (Table 1 and Fig. 1). Infact, *L. cor-*

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niculatus was found at only 8 (8.1%) of the 99 sites investigated, and all individuals found were the alien variety, *L. corniculatus* var. *corniculatus*. On the other hand, white clover, *T. repens*, and Japanese clover, *Kummerovia striata* (Fabaceae), which are both candidate food plants, were observed at 90 (90.9%) and 28 (28.3%) of the 99 study sites, respectively. Furthermore, of the 43 sites where *Z. emelina* adults were seen in this study, *T. repens* and *K. striata* were found at 43 (100%) and 16 (37.2%) sites, respectively, with eggs and/or larvae on these plants at 16 and 4 sites, respectively (Table 1).

All eight sites where *L. corniculatus* was found in this study were grassy ateas in the Senri Hills, and adult *Z. emelina* were seen at two (T49 and S7) of the eight sites (Table 1 and Fig. 1). However, *T. repens* was also found at these two sites, and eggs of *Z. emelina* were observed on *T. repens* at one of these sites (S7).

The present results show that the OIA population depends more on *T. repens* and/or *K. striata* as larval food plants rather than *L. corniculatus*, which has previously been considered the major food plant in that area (Tohyama, 1989) and in other areas in Japan (*e. g.* Fukuda *et al.*, 1984). The Senri population is small and included only two sites at which *Z. emelina* co-occurred with *L. corniculatus* (T49 and S7). It is possible that this population is a relict of the *L. corniculatus*-dependent populations of northern Osaka. In contrast it is probable that four sites at Machikaneyamacho (T31–T32, T34–T35) are satellite sites of the OIA population, because *T. repens* but not *L. corniculatus* was found at these sites.

Seasonal occurrence of adults

Adult *Z. emelina* were observed around the OIA between May and October in 2002, and between April and November in 2003 and 2004 (Fig. 2). The density of adults was higher between August and October than between April and June. The earliest record of an adult during the study period was on April 17, 2004 when a male was seen at site T6. The latest record was on November 28, 2004 at sites I6, T5 and T6.

Seasonal fluctuations in the densities of adults correspond to there being six to seven peaks of adult occurrence in the area around the OIA each year: there were 7 peaks in 2004, in late April, late June, mid-July, early August, early September, late September–early October and late October–early November, with durations of half a month to two months. Similarly, there were six peaks in both 2002 and 2003. The results of rearing eggs, larvae and pupae of *Z. emelina* under quasi-natural conditions show that it takes less than one month to complete the whole immature stage when rearing is preformed between August and October, so it is possible that these peaks of adult occurrence correspond to the adult flight period of each generation in the field around the OIA.

Watanabe (2005) reported some adult *Z. emelina* from the bank of the Inagawa River in early December. In the present study, no adults were seen at sites T5 and T6 on December 14, 2004, but eggs and larvae were found on the leaves of *T. repens*, so we consider that the flight season of adults ends in mid-December and the larvae overwinter in the fields around the OIA.

Rearing experiments yielded the intriguing finding that a total of nine adult female *Z. emelina* from the OIA population produced no male offspring (*i. e.* all adult F_1 were female). This was observed for the first time for a female captured at T6 in 2002. In 2003 this phenomenon was observed for four females out of an unknown sample size. In 2004 it was observed for five (18.5%) of 27 females used in the rearing experiment. In some butterflies such as *Eurema hecabe* (Hiroki *et al.*, 2004), *Hypolimnas bolina* (Mitsuhashi *et al.*, 2004) and *Acrea* spp. (Hurst *et al.*, 1999), a failure to produce male offspring is caused by parasiti-

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sation or symbiosis by bacteria such as *Wolbachia* spp., so in the future bacteriological studies of female *Z. emelina* that produce no male offspring should be performed to determine the cause of this phenomenon.

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摘　　要

大阪国際空港周辺におけるシルビアシジミの分布と季節消長 (蓑原　茂・森地重博・平井規央・石井　実)

大阪・兵庫府県境に位置する大阪国際空港 (以下, 大阪空港) 周辺の99ヶ所の草地 (過去の生息地を含む) において, 2000–2007年にシルビアシジミの分布と季節消長の調査を行った. また, 野外における本種の食草を明らかにし, 発育期間を推定するために, 野外で採集した雌から採卵し, 準野外条件で成虫まで飼育した. その結果, シルビアシジミの成虫が43ヶ所で確認された. この43ヶ所のうち, 15, 21ヶ所はそれぞれ, 大阪空港周辺の猪名川河川敷と市街化地域の草地であった. それに対して, 本種は大阪空港の北東部にある千里丘陵では7ヶ所からしか確認できなかった. 成虫の密度は, とくに大阪空港周辺の12ヶ所と千里丘陵の1ヶ所で高かった. この調査の結果, 大阪空港周辺には, 日本における主要な寄主植物であるミヤコグサはなく, その個体群はシロツメクサまたはヤハズソウを利用していることも明らかになった. それに対して, 千里丘陵では2ヶ所で本種とミヤコグサ (セイヨウミヤコグサ) の両方が見られ, 卵も確認された. 野外調査と飼育実験の結果から, 本種は大阪空港周辺では, 成虫期を4–11月として6–7世代を経過すると推定された. 興味深いことに, 野外で採集した一部の雌成虫からは雄の子孫は得られなかった (すなわち, すべての子世代は雌成虫になった).

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